NOx Control Cost Effectiveness Estimate

Engine Manufacturer	General Electric
Model No.	LM 1600
Unit ID	12A
Fuel Used	Natural Gas
Emissions Control	SCR
Combustion Control Purpose	NOx
Target Reduction	95%

Color Legend
- User Data / Information Input Cell
- "Cumulative" Cost Cell for Primary Categories
- Cost Effectiveness ($ / ton)

1 Engine Design Conditions

			Comments
Power Output	19200	(hp)	Rated HP
Engine Exhaust Temperature		(F)	*optional input*
Engine Exhaust Rate		(lb/hr)	*optional input*
Gas Volume		(dscfm)	*optional input*

2 Full Load Engine Exhaust Composition:

			Comments
Oxygen (O_2)		(vol. %)	*optional input*
Carbon Dioxide (CO_2)		(vol. %)	*optional input*
Water (H_2O)		(vol. %)	*optional input*
Oxides of Nitrogen (NOx)		(ppmvd)	*optional input*
Nitrogen (N_2)		(vol. %)	*optional input*
NOx	52.7 lb/hr	0.366 (lb/MMBtu)	NOx emissions from test Data: 373.0 lb/MMSCF ~0.37 lb/MMBtu

3 Engine Parameters

				Comments
Total Operating Hours per Season	8760	(hrs)	100% utilization	

4 Final Exhaust Gas Composition

			Comments
Oxides of Nitrogen (NOx)	2.6 lb/hr	0.018 (lb/MMBtu)	Assume 75% reduction

5 Economic Parameters

			Comments
Source of Cost Data	see Analysis		Analysis primarily relying on EPA Cost Manual

Direct Costs		**Cost Formula**	**Comments**
Combustion Control Equipment and Auxiliary Equipment	$3,712,500	(A)	Based on EPA control cost manual ($167/kw; adjust to 2020$) ?
Instrumentation	$371,250	(0.1*A)	Calculated Cost using EPA Control Cost Manual
Sales Taxes	$0	(0.03*(A+instrumentation))	3% Sales Tax in this example
Freight	$185,625	(0.05*A)	Calculated Cost using EPA Control Cost Manual
Purchased Equipment Cost (PEC)	**$4,269,375**	PEC	

6 Direct Installation Costs

		Cost Formula	**Comments**
Foundations and Supports	$341,550	(0.08*PEC)	Calculated Cost using EPA Control Cost Manual
Handling and Erection	$597,710	(0.14*PEC)	Calculated Cost using EPA Control Cost Manual
Electrical	$170,780	(0.04*PEC)	Calculated Cost using EPA Control Cost Manual
Piping	$85,390	(0.02*PEC)	Calculated Cost using EPA Control Cost Manual
Insulation for ductwork	$42,690	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Painting	$42,690	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Site Preparation	$0	SP	As required
Buildings	$0	Bldg	As required
Total Installation Cost (TIC)	**$1,280,810**		
Total Direct Costs (PEC+TIC)	**$5,550,185**		

7 Indirect Costs

		Cost Formula	**Comments**
Engineering	$426,938	(0.10*PEC)	Calculated Cost using EPA Control Cost Manual
Construction and field expenses	$213,469	(0.05*PEC)	Calculated Cost using EPA Control Cost Manual
Contractor fees	$426,938	(0.10*PEC)	Calculated Cost using EPA Control Cost Manual
Start-up	$85,388	(0.02*PEC)	Calculated Cost using EPA Control Cost Manual
Performance test	$42,694	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Contingencies	$128,081	(0.03*PEC)	Calculated Cost using EPA Control Cost Manual
Total Indirect Costs (IC)	**$1,323,506**	(0.31*PEC)	

8 Capital Cost Summary

		Comments
Total Direct Capital Costs (DC)	$5,550,185	
Total Indirect Capital Costs (IC)	$1,323,506	
Total Capital Investment (TCI)	**$6,873,691**	

9 Direct Annual Costs

		Cost Formula	**Comments**
Operator Labor	$12,500	nominal cost	0.5 hr/shift; example from similar EPA analysis
Supervisor Labor	$1,875		15% of operator
Operating Materials - ammonia	$54,289		materials estimate annual NH3 at $700 per ton; 1.1 molar ratio
Maintenance - Labor	$12,500	nominal cost	0.5 hr/shift; rate example from EPA
Maintenance - Materials	$5,000	nominal cost	Engineering Estimate
Catalyst maintenance / replacement	$185,625		Engineering Estimate (5% of Cap Cost)
Testing and QA/QC	$20,000		Engineering estimate - Annual test; reagent controller QA
Electricity	$2,500		Estimate based on analysis in PA DEP TSD
Total Direct Annual Costs	**$294,289**		

10 Indirect Annual Costs

		Cost Formula	**Capital Recovery Factor**	**Comments**		
Overhead	$19,125	(0.6*(OL+SL+ML+MM))				
Administrative Charges	$137,474	(0.02*TCI)		Engine ACT Document		
Property Taxes	$68,737	(0.01*TCI)		Engine ACT Document		
Insurance	$68,737	(0.01*TCI)	**CRF**		20.0000	30.0000
Capital Recovery	$362,244	CRF[TCI]	0.0527	Factor for costs annualized over 20 years at 5% interest.	0.0500	0.0325
Total Indirect Annual Costs	**$656,316**			CRF = i * (1+i)^n / [(1+i)^n - 1] (i expressed as a decimal - e.g., 10% = 0.1)	0.0802	0.0527

11 Summary

			Comments
Total Direct Annual Operating Costs	$294,289		
Total Indirect Annual Operating Costs	$656,316		
Total Annual Costs	$950,605	$50 $ per hp	
Incremental Annual Costs Over Baseline	$950,605		

12 Annual Emissions Reduction Over Baseline

		Comments
Oxides of Nitrogen (NOx)	219.30 (Tons)	

Cost Effectiveness ($/Ton)

		Comments
Oxides of Nitrogen (NOx)	$4,335	

NOx Control Cost Effectiveness Estimate

Engine Manufacturer	Cooper-Rolls
Model No.	Avon
Unit ID	12B
Fuel Used	Natural Gas
Emissions Control	SCR
Combustion Control Purpose	NOx
Target Reduction	95%

* per WESTAR O&G report

Color Legend

User Data / Information Input Cell
"Cumulative" Cost Cell for Primary Categories
Cost Effectiveness ($ / ton)

1 Engine Design Conditions

			Comments
Power Output	14300	(hp)	Rated HP
Engine Exhaust Temperature		(F)	*optional input*
Engine Exhaust Rate		(lb/hr)	*optional input*
Gas Volume		(dscfm)	*optional input*

2 Full Load Engine Exhaust Composition:

			Comments
Oxygen (O_2)		(vol. %)	*optional input*
Carbon Dioxide (CO_2)		(vol. %)	*optional input*
Water (H_2O)		(vol. %)	*optional input*
Oxides of Nitrogen (NOx)		(ppmvd)	*optional input*
Nitrogen (N_2)		(vol. %)	*optional input*
NOx	23.1 lb/hr	0.170 (lb/MMBtu)	NOx emissions from test Data: 173.9 lb/MMSCF ~0.170 lb/MMBtu

3 Engine Parameters

				Comments
Total Operating Hours per Season	8760	(hrs)	100% utilization	

4 Final Exhaust Gas Composition

			Comments
Oxides of Nitrogen (NOx)	1.2 lb/hr	0.009 (lb/MMBtu)	Assume 75% reduction

5 Economic Parameters

			Comments
Source of Cost Data	see Analysis		Analysis primarily relying on EPA Cost Manual

Direct Costs		**Cost Formula**	**Comments**
Combustion Control Equipment and Auxiliary Equipment	$2,765,000	(A)	Based on EPA control cost manual ($167/kw; adjust to 2020$)
Instrumentation	$276,500	(0.1*A)	Calculated Cost using EPA Control Cost Manual
Sales Taxes	$0	(0.03*(A+instrumentation))	3% Sales Tax in this example
Freight	$138,250	(0.05*A)	Calculated Cost using EPA Control Cost Manual
Purchased Equipment Cost (PEC)	**$3,179,750**	PEC	

6 Direct Installation Costs

		Cost Formula	**Comments**
Foundations and Supports	$254,380	(0.08*PEC)	Calculated Cost using EPA Control Cost Manual
Handling and Erection	$445,170	(0.14*PEC)	Calculated Cost using EPA Control Cost Manual
Electrical	$127,190	(0.04*PEC)	Calculated Cost using EPA Control Cost Manual
Piping	$63,600	(0.02*PEC)	Calculated Cost using EPA Control Cost Manual
Insulation for ductwork	$31,800	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Painting	$31,800	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Site Preparation	$0	SP	As required
Buildings	$0	Bldg	As required
Total Installation Cost (TIC)	**$953,940**		
Total Direct Costs (PEC+TIC)	**$4,133,690**		

7 Indirect Costs

		Cost Formula	**Comments**
Engineering	$317,975	(0.10*PEC)	Calculated Cost using EPA Control Cost Manual
Construction and field expenses	$158,988	(0.05*PEC)	Calculated Cost using EPA Control Cost Manual
Contractor fees	$317,975	(0.10*PEC)	Calculated Cost using EPA Control Cost Manual
Start-up	$63,595	(0.02*PEC)	Calculated Cost using EPA Control Cost Manual
Performance test	$31,798	(0.01*PEC)	Calculated Cost using EPA Control Cost Manual
Contingencies	$95,393	(0.03*PEC)	Calculated Cost using EPA Control Cost Manual
Total Indirect Costs (IC)	**$985,723**	(0.31*PEC)	

8 Capital Cost Summary

		Comments
Total Direct Capital Costs (DC)	$4,133,690	
Total Indirect Capital Costs (IC)	$985,723	
Total Capital Investment (TCI)	**$5,119,413**	

9 Direct Annual Costs

		Cost Formula	**Comments**
Operator Labor	$12,500	nominal cost	0.5 hr/shift; example from similar EPA analysis
Supervisor Labor	$1,875		15% of operator
Operating Materials - ammonia	$23,789		materials estimate annual NH3 at $700 per ton; 1.1 molar ratio
Maintenance - Labor	$12,500	nominal cost	0.5 hr/shift; rate example from EPA
Maintenance - Materials	$5,000	nominal cost	Engineering Estimate
Catalyst maintenance / replacement	$138,250		Engineering Estimate (5% of Cap Cost)
Testing and QA/QC	$20,000		Engineering estimate - Annual test; reagent controller QA
Electricity	$2,500		Estimate based on analysis in PA DEP TSD
Total Direct Annual Costs	**$216,414**		

10 Indirect Annual Costs

		Cost Formula	**Capital Recovery Factor**	**Comments**
Overhead	$19,125	(0.6*(OL+SL+ML+MM))		
Administrative Charges	$102,388	(0.02*TCI)		Engine ACT Document
Property Taxes	$51,194	(0.01*TCI)		Engine ACT Document
Insurance	$51,194	(0.01*TCI)	**CRF**	
Capital Recovery	$269,793	CRF[TCI]	0.0527	Factor for costs annualized over 20 years at 5% interest.
Total Indirect Annual Costs	**$493,695**			CRF = i * (1+i)^n / [(1+i)^n - 1] (i expressed as a decimal - e.g., 10% = 0.1)

11 Summary

			Comments
Total Direct Annual Operating Costs	$216,414		
Total Indirect Annual Operating Costs	$493,695		
Total Annual Costs	$710,109	$50 $ per hp	
Incremental Annual Costs Over Baseline	$710,109		

12 Annual Emissions Reduction Over Baseline

		Comments
Oxides of Nitrogen (NOx)	96.10 (Tons)	

Cost Effectiveness ($/Ton)

		Comments
Oxides of Nitrogen (NOx)	$7,390	